ALLOY COMPOSITION FOR MAKING BLISTER-FREE ALUMINUM FORGINGS AND PARTS MADE THEREFROM

Field of the Invention

[0001] This invention relates to the field of aluminum alloys, particularly, forged parts made from such alloys. This invention further relates to forged aluminum parts, including but not limited to vehicle wheels, especially aerospace or aircraft wheels, and various aluminum brake components, including but not limited to various vehicular brake piston housings.

Background of the Invention

[0002] It has been known for years that aluminum alloy products may be subject to degradation as a result of an oxidation process that occurs during extended exposure to high temperatures in the presence of water vapor. This process, which is called high temperature oxidation (or "HTO"), results from the introduction of hydrogen at or near the product surface, which subsequently collects and forms pores or blisters that are detrimental to the performance of that product. In a simplistic form, the chemical reaction associated with HTO can be written as:

$$3H_2O + 2Al > Al_2O_3 + 3H_2.$$

In some cases, the pores and blisters associated with HTO need to be removed from the surface by grinding and machining which is both costly and time consuming. In still other cases, such porosity is so extensive that the parts must be scrapped.

[0003] The occurrence of HTO is especially problematic in complex forged products because the material for making those parts have to be heated many times for forging in separate dies to achieve the desired final configuration. The amount of water vapor present as atmospheric humidity is also an important factor, it being noted that HTO is often more prevailing when absolute humidity is high.

[0004] A series of experiments were run varying the composition of aluminum alloy 2014 (Aluminum Association designation), to hopefully achieve higher tensile elongation and fracture toughness properties. From those experiments, it was observed that forgings manufactured from one newly cast, set of compositions had unusually low occurrences of HTO. This invention focuses on the performance of that set of compositions for which HTO resistance, and the surface blistering associated therewith, has exhibited a significant improvement, especially over its 2014 forged counterparts.

Relevant Art

[0005] 2014 aluminum, as registered by the Aluminum Association ("AA"), comprises: 0.5-1.2 wt.% silicon, 3.9-5.0 wt.% copper, 0.4-1.2 wt.% manganese, 0.2-0.8 wt.% magnesium, 0.7max wt% iron, up to about 0.25 wt.% zinc, up to about 0.15 wt.% titanium, up to about 0.1 wt.% chromium, the balance aluminum. But the operational preferences for 2014 aluminum drift into the high side of that Si range. By contrast, 2214 aluminum (also AA-registered), has a lower iron content, with a maximum of 0.3 wt.% Fe. The operational limits for 2214 aluminum also "prefer" a Si maximum of about 0.9 wt.%.

[0006] In addition, there are several U.S. Patents pertinent to the manufacture of Al-Cu alloys, or to the making of forged aluminum parts. Representative of these are: U.S. Patent Nos. 4,818,308, 5,032,359, 5,219,617, 5,462,712, 5,630,889, 5,652,063, 5,665,306, 5,738,735, 5,775,892, 5,800,927, 5,851,320, 5,865,911, 6,053,997 and 6,056,835. Unlike many of the foregoing compositions, the alloy composition of this is invention, is also cadmium-free, lithium-free and silver-free, as well as being very low in intentional iron additions. By taking precautions to significantly reduce the iron contents of this invention alloy, to a lot less than the typical Fe content of about 0.5% iron in 2014 aluminum, and to about half the typical 0.3% Fe content for 2214 aluminum, and through the exercise of much tighter controls over the ranges for its other main alloying components, this invention achieves a totally distinct ingot structure. As a result of said structure, the alloy composition of this invention also exhibits improved fracture toughness performance over its 2014 counterparts.

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Summary of the Invention

[0007] There is claimed an improved aluminum alloy with reduced susceptibility to high temperature oxidation and the blistering effects thereof. This alloy also exhibits improved fracture toughness performance. The alloy consists of: about 0.65-0.9 wt.% silicon, about 4-4.7 wt.% copper, about 0.6-0.9 wt.% manganese, about 0.35-0.55 wt.% magnesium, up to about 0.25 wt.% zinc, up to about 0.15% iron, up to about 0.15 wt.% titanium, up to about 0.1 wt.% chromium, and up to about 0.001wt.% beryllium, the balance aluminum, incidental elements and other impurities. More preferably, this alloy

contains about 0.7-0.85 wt.% silicon, about 4.1-4.5 wt.% copper, about 0.65-0.85 wt.% manganese, about 0.4-0.5 wt.% magnesium, about 0.14 wt.% iron or less, and a balance of aluminum, incidental elements and impurities. It is especially suitable to make aerospace wheel forgings, more particularly inboard aircraft wheels, and various brake components, like a brake piston housing, from the aforesaid alloy composition.

[0008] The essence of this invention's compositional change, over both 2014 and 2214 aluminum, is: (1) a reduction in the amount of Fe present, by purposefully reducing the iron contents thereof; and (2) a purposeful tightening of the compositional range limits for this alloy's other main alloying components. In this "higher purity" state, noticeable improvements to blistering resistance and, hence, significantly lower scrap rates are achievable, at commercial production levels. In addition, greater fracture toughness performance has been observed.

Brief Description of the Drawings

[0009] Further features, objectives and advantages of this invention will become clearer when reviewing the preferred embodiments hereof made with reference to the accompanying drawings wherein:

[0010] FIGURE 1 is a photograph of a forged part made from the invention alloy (left) versus the same part made from 2014 aluminum (right), under ultraviolet light to show a fluorescent die, i.e. the speckled portions on the right forged part, that flags areas of HTO defect or blistering on said part;

[0011] FIGURE 2 is a close-up of the lower portions to the two comparative parts shown in FIGURE 1; and

[0012] FIGURE 3 is a side-by-side comparison of two micrographs (500x magnification) of sections to both parts of FIGURE 1.

Detailed Description of Preferred Embodiments

[0013] For any description of preferred alloy compositions herein, all references to percentages are by weight percent (wt.%) unless otherwise indicated. When referring to any numerical range of values, such ranges are understood to include each and every number and/or fraction between the stated range minimum and maximum. A range of about 4-4.7 wt.% copper, for example, would expressly include all intermediate values of about 4.01%, 4.03% and 4.05% all the way up to and including 4.55%, 4.65% and 4.69% Cui. The same rule applies to every other elemental range and/or property value set forth hereinbelow.

[0014] As used herein, the term "substantially-free" means having no significant amount of that component purposefully added to the alloy composition, it being understood that trace amounts of incidental elements and/or impurities may find their way into a desired end product. For example, a substantially cadmium-free alloy might contain less than about 0.1% Cd, or less than about 0.03% Cd on a more preferred basis, due to contamination from incidental additives or through contact with certain processing and/or holding equipment. All embodiments of the present invention are substantially free of lithium and silver on a most preferred basis.

[0015] In a series of experiments involving variations of alloy 2014 (Aluminum Association designation), the composition was purposefully adjusted with the intent of improving tensile elongation performance. From those experiments, it was also observed that forgings manufactured from newly cast alloy compositions had an unusually low occurrence of HTO. Upon further investigation, it was noted that the Fe-Mn-Si constituents of this new alloy composition are more highly refined as compared to the same constituents in its conventional 2014 counterpart. While the inventors do not wish to be tied to any particular theory for the improved HTO (or blister-resistance) performance of this invention, it is postulated that the refined microstructure associated with the new alloy described hereinbelow contains fewer sites for the nucleation of hydrogen-induced porosity. Thus, the lower occurrence of blistering and other objectionable surface defects on products made, especially forged, from the composition of this invention.

[0016] Additional trials were run on specific forging configurations that had been especially susceptible to HTO-related defects in past years. When the modified alloy was used for forging these same parts/configurations, there was no evidence of HTO. The alloy composition of this invention was then adopted for these most susceptible configurations. Over the course of the next 6 months, occurrences of HTO was reduced by about 93%. And, when any occurrences of HTO was observed in that six month trial period, further investigation showed that the HTO-susceptible pieces were actually manufactured from a composition OTHER THAN the invention alloy herein. Thus, it

can be concluded that use of this alloy invention virtually eliminates susceptibility to HTO. A table comparing preferred embodiments of this Invention with its 2014 preferred counterpart follows.

Table 1 – Comparison w/ 2014 Aluminum

	2014		Invention Alloy	
	Min.	Max.	Min.	Max.
Si	0.5	1.2	0.7	0.85
Fe		0.7		0.14
Cu	3.9	5	4.1	4.5
Mn	0.4	1.2	0.65	0.85
Mg	0.2	0.8	0.4	0.5
T6 Fract Tough (ksi √in)	20.6		28.2	

EXPERIMENT:

[0017] In order to evaluate the effect of a new alloy composition on HTO susceptibility, a comparative trial was conducted using the new alloy on a forging configuration that had historically exhibited high HTO occurrences. This particular die forging configuration, for an aircraft wheel, was manufactured using standard 2014 and the new alloy composition of this invention. After the forgings were manufactured, they were inspected using a fluorescent die penetrant per ASTM Standard No. E1417, the disclosure of which is fully incorporated by reference herein. The small blisters and surface voids characteristic of HTO, often detected using this inspection technique, also detect cracks and other objectionable surface features. These photographs, FIGURES 1 and 2 below, show the same forgings made from two distinct alloy compositions. Using

an ultraviolet light, the fluorescent die-laced comparative forgings clearly display how these modifications to alloy composition (from known 2014 practices) clearly show a marked improvement in performance, i.e. significantly reduced occurrences of HTO-type 'blistering", or the numerous "white spots" in the right side wheel in both FIGURES 1 and 2.

[0018] The precise compositions of the forgings depicted in FIGURES 1 and 2 are summarized in accompanying Table 2:

Table 2- Compositions of UV Tested Forged Parts

	2014 Forging	**Invention Alloy**
wt. % Si	0.83	0.79
Cu	4.52	4.55
Mn	0.66	0.72
Mg	0.47	0.45
Fe	0.41	0.11

Prior to the adoption of this new alloy composition, scrap rates in the manufacture of aircraft wheels from 2014 aluminum AVERAGED 16% per year for the previous 3 years. In addition to lost wheels, too far damaged to recover by rework, there were others which while not so far damaged as to require scrapping, nevertheless required additional processing steps (including sanding, repolishing) prior to release to the ultimate consumer of such goods. Through the manufacture of these more HTO- susceptible parts from the alloy composition of this invention, scrap rates are now running at 0%.

[0019] Having described the presently preferred embodiments, it is to be understood that the invention may be otherwise embodied within the scope of the appended claims.

[0020] What is claimed is:

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